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AGRICULTURAL EXPERIMENT STATION

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SOME FUNGOUS DISEASES OF THE GRAPE.

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KNOXVILLE, TENNESSEE, U. S. A.

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BOTANICAL DIVISION.

SOME FUNGOUS DISEASES OF THE GRAPE.

BY F. LAMSON-SCRIBNER.

INTRODUCTORY.*

The grape industry of our country has suffered repeated and severe checks through the attacks of numerous insect and plant parasites, and viticulturists have to be ever on the alert to protect their vines from these persistent and nearly omnipresent foes. Among the many plant parasites are to be counted the fungus of anthracnose or bird's-eye-rot, the fungus of brown-rot or downy mildew, and the fungus of black-rot. The last named is deemed the worst enemy of all. Many have been forced to abandon grape-culture, and many more have been deterred from engaging in this industry solely on account of the destructiveness of this pest. Descriptions of these vine diseases have been frequently published and their causes repeatedly pointed out, yet there are many grape-growers in our State who, not having access to that which has already been printed upon this subject, will, we are confident, be glad to have what is now known presented to them directly in the shape of a Bulletin. And further, the grape interests may readily become of such prime importance in this State that anything relating to the protection of the grape crop cannot be too often repeated.

A most thorough study of the characters and habits of these parasites has led to a knowledge of their life-histories and enabled us to experiment intelligently in treating them. These experiments have been finally crowned with success, and we can now prescribe a practical course of treatment, which will not only preserve our vines from the ravages of anthracnose and downy mildew, but also from that more serious disease—black-rot.

*Figures 20 and 21 were obtained from the U. S. Dept. Agr.: all others in this Bulletin are from cuts kindly loaned us by J. T. Lovett Company, Little Silver, New Jersey.

I. BLACK-ROT.

In the older grape-growing States east of the Mississippi this disease has been recognized for forty years or more, and it has been a frequent theme for discussion in our agricultural and horticultural journals, but only within a short time has the true cause of the malady been ascertained. In no State has its ravages been more severe than in Tennessee, and the culture of the vine, undertaken and continued for a time with flattering promises of success, has been repeatedly abandoned because of the complete destruction of the fruit by the rot. Experiments made by this Station, an account of which is given further on, assure us that the disease may be here overcome and good crops made reasonably certain.

CAUSE OF BLACK-ROT.

Black-rot has been attributed to the character of the soil, to the atmosphere, to an enfeebled condition of the vines, etc., etc., but it is now known to be solely due to the attacks of a plant parasite—a fungus of microscopic size, but no less a plant, possessing characters of its own as definite as those of the vine itself. The habits of this fungus, the manner of growth, and the conditions which favor or are unfavorable to its development, are now well known; we know how and when it produces its reproductive bodies, named spores, and when and how these spores come upon the vine, and, finally, how the attacks of the fungus may be prevented.

Like other plants, the fungus of black-rot has both vegetative and reproductive organs. The former, instead of consisting of root, stem and leaves, consists of exceedingly fine thread-like growths called the *mycelium;* the latter, instead of consisting of flowers and seeds, are curiously formed bodies designed to hold the very simple and very minute seeds, named by the botanist *spores.*

THE VEGETATIVE PART OR MYCELIUM OF THE BLACK-ROT FUNGUS.

The vegetative part or mycelium of the black-rot fungus is made up of slender filaments, that are really very fine tubes, interlaced and more or less grown together (Figure 15,) These filaments vary in diameter from 1–10,000 to 1–5,000 of an inch, have frequent cross-walls, and are filled with a clear but finely granular fluid — the protoplasm. When a vine or its fruit is attacked by this fungus we may see, with the aid of the compound microscope, this mycelium in the tissues of the

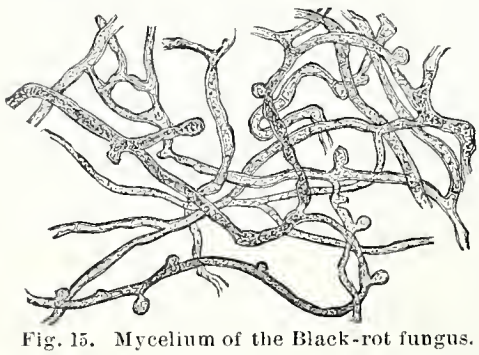
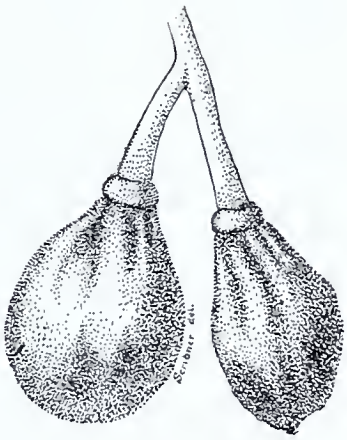
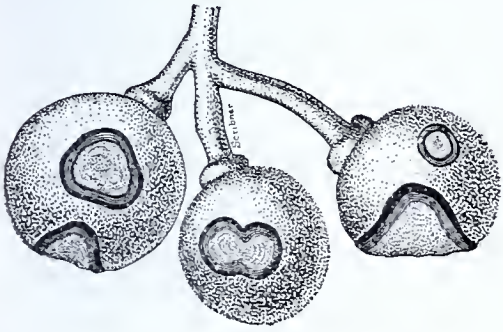


Fig. 15. Mycelium of the Black-rot fungus.

1. BLACK-ROT.



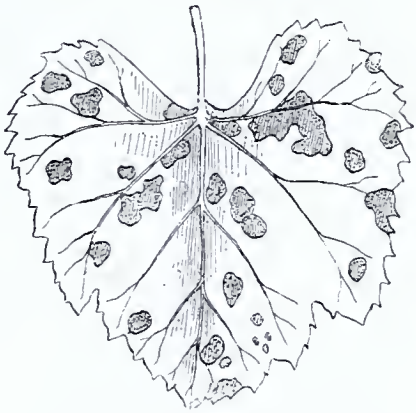
2. BROWN-ROT.



3. BIRD'S-EYE-ROT.

4 ANTHRACNOSE.

5. GRAPE-LEAF BLIGHT.



6. BLACK-ROT ON THE LEAF.

THE ROTS AND BLIGHT OF THE GRAPE.

affected parts. It grows between and often penetrates the cells composing the tissues, and from them absorbs the nourishment which is required for its growth.

ORGANS OF REPRODUCTION.

While the berry is yet only in part destroyed, the mycelium just beneath the cuticle or skin begins to form little rounded sacks, which are quite firm in texture, and, as in their growth they distend the cuticle, they may be seen externally studding the surface of the berry like little pimples. One can see these without the aid of a magnifier, and their presence at once distinguishes black-rot from brown-rot, for there are no such developments in the latter disease. A vertical section through one of the spore-sacks, is shown in figure 16, very highly magnified.

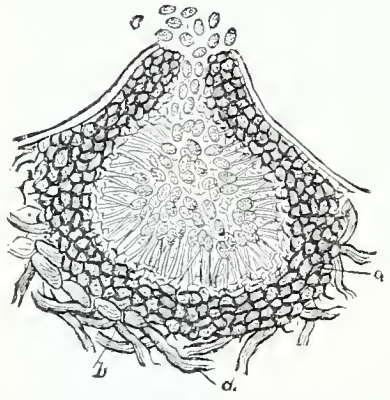


Fig. 16. A vertical section of a pycnidium or spore-sack, illustrating the phoma-stage of the black-rot fungus. The spores shown in the interior are borne on slender stalks. They escape through an opening at the summit.

A dense black growth of the mycelium forms the wall of the sack, and in the interior the spores, yet attached to their slender stalks are shown, as well as others that have separated from their supports and are seen escaping through the natural opening at the top. These spores are oval or oblong in shape and colorless.

Mingled with the sacks like the one above described are others which in section appear like figure 17. These contain much smaller and very slender spores. Both kinds of spores are produced in vast numbers, and each spore has the power to produce a new growth of the fungus. Like the seeds of higher plants, they serve to propagate the species, and, scattered by the wind and rains, they may quickly spread the disease over the vineyard, or from one vineyard to another. They possess a high degree of vitality; even when kept thoroughly dry for months they readily germinate if placed in suitable conditions. The appearance in germination of some of the spores first described—the phoma spores—or more properly, stylospores—is shown in fig. 18.

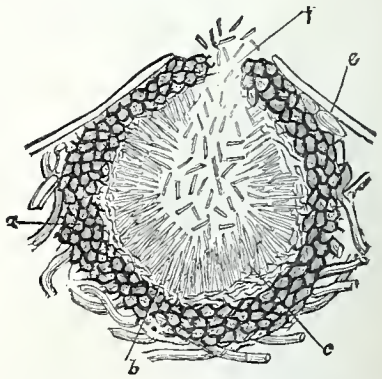


Fig. 17. A vertical section, through a spermogonium or sack in which are formed the spermogonial spores of black-rot, shown in the interior of the cavity.

Falling upon a moistened grape-leaf or berry, these spores push forth slender germ tubes, which enter the tissues within, either through the breathing pores (stomata), or, as is more frequently the case, by boring directly

through the cuticle and epidermis. Once in the interior of the leaf or berry, only the destruction of the latter can prevent the further growth of the fungus or the consequent development of disease.

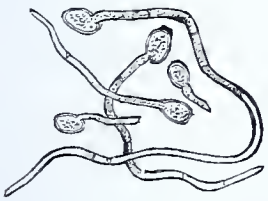


Fig. 18. Germinating stylospores.

When fully matured the black-rot fungus produces spores of yet another kind. These can be found only in early spring in berries that have been destroyed by the disease the year previous, a fact which shows that the fungus retains its vitality in the rotten berries throughout the winter season. They are developed within thick-walled receptacles similar to those already mentioned and are again enclosed, in parcels of eight, within very thin-walled, transparent, elongated sacks, illustrated in figure 19.

Fig. 19. Two spore sacks in the final stage of the black-rot fungus.

It is probable that these spores are specially designed to perpetuate the parasite from year to year, for the fungus evidently dies as soon as their development ceases and becomes itself a prey to other fungi.*

PARTS OF THE VINE ATTACKED.

The green and tender shoots, the leaves and the berries are all subject to the attacks of the black-rot fungus. As the result of the action of the mycelium upon the tissues of the several parts infested, certain changes in the tissues take place, which finally become manifest to the naked eye, appearing in the berry as black-rot and on the leaves as sharply defined, reddish brown spots (see Plate VI), and on growing canes as elongated, dark brown or black spots, which are slightly depressed, owing to the absorption of the juices from the cells composing the underlying tissues. Usually but little damage results from the attacks made upon the shoots or the leaves; it is only when the berries are attacked that the injury becomes serious.

The time from when the fungus first attacks the berries till these begin to show signs of decay, is, under ordinary circumstances, about eight days. In the last stages of the disease the berries become wholly black and shrivel up into a dry, hard mass, there being little left but the skin and seeds, (see Plate VI. fig. 1). The appearance of a grape cluster, which has been severely attacked by this form of rot, is shown in figure 20, on the next page.

CONDITIONS FAVORING THE DISEASE.

Moisture is necessary and a considerable degree of heat favors the development of the disease. In the more northern grape-growing districts black-rot, although usually present, does comparatively little or

* A full account of the fungus of black-rot, by Viala and Scribner, was published by the U. S. Department of Agriculture, in Bulletin No. 7 of the Botanical Division.

perhaps no direct damage, and in the dry regions of the far West, especially in California, the disease is unknown. In this latitude the disease is most virulent, and here weather conditions most favorable to the development of the fungus occur, viz: frequent rains followed by hot, sultry weather or heavy dews and fogs, with a marked change of temperature between day and night.

It is well known that some varieties of grapes are more subject to the attacks of black-rot than others, or as we say, they are more "susceptible" to the disease. What the peculiar characters are which render some vines more susceptible than others is not definitely known. In general terms it may be said that vines of rank, succulent growth and with juicy berries are those which are most subject to the attacks of the fungus.

Fig. 20. A cluster of grapes destroyed by black-rot.

TREATMENT OF BLACK-ROT.

Early in the spring of 1889 it was decided to make experiments here in treating black-rot with the sulphate of copper (bluestone) compounds. A spraying-pump, of the knapsack kind, named the "Eureka," was purchased of Adam Weaber & Son, of Vineland, New Jersey, with which to make the proposed applications of remedies. This pump is made entirely of copper, so it is perfectly resistant to the caustic action of the compound used, and is fitted with a modified cyclone or "Riley" nozzle, through which the somewhat thick Bordeaux mixture passes readily. The manner of carrying and operating this style of pump is shown in figure 21.

The vineyard which seemed to us best suited for making experiments was one located some six miles north of Knoxville, on the southern slope of a steep hillside, and owned by Mr. J. T. Allen, who kindly afforded us every possible facility and much direct assistance in the prosecution of our work. The vines had been well cared for, properly pruned and trained, and were in excellent condition. Black-rot was in the vineyard, however, and in 1888 the crop was a failure because of the disease, fully 95 per cent. of the berries having been destroyed. This thorough infection of the vineyard served to severely test the

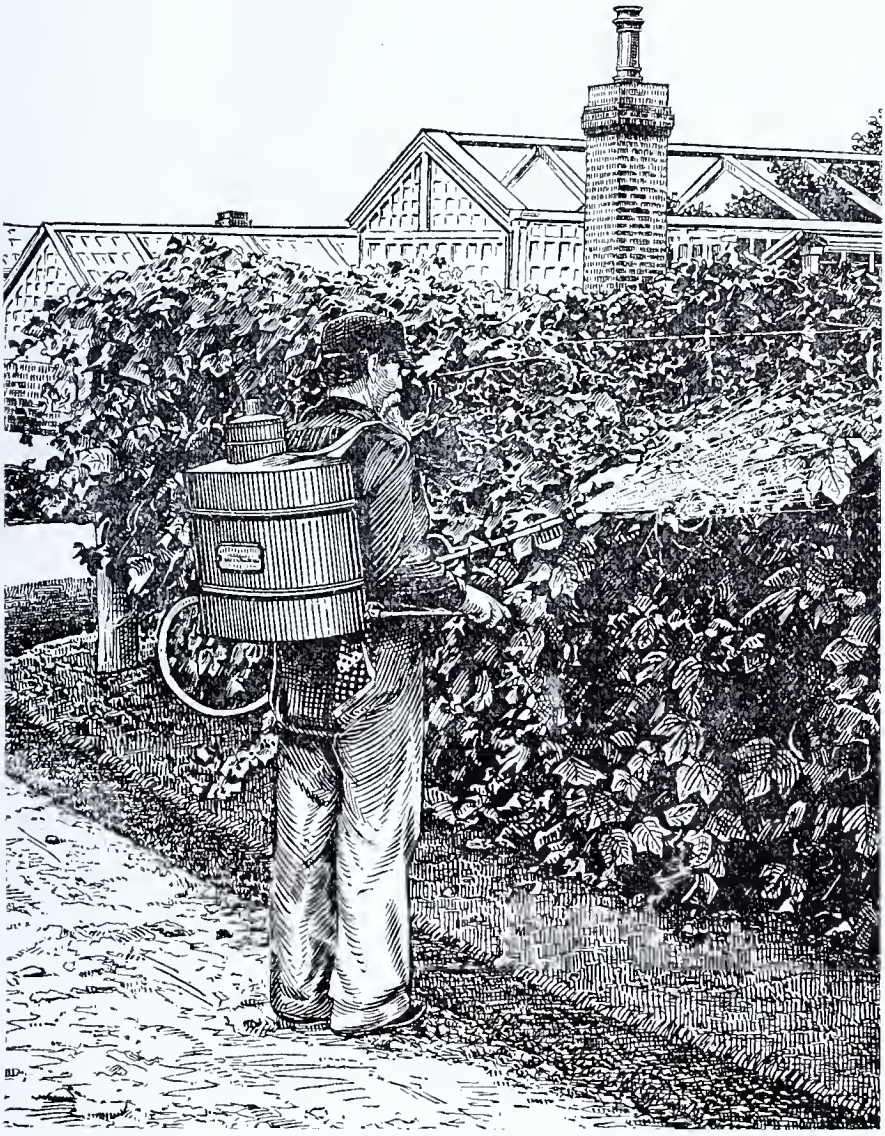


Fig. 21. Spraying vines with the Eureka Sprayer.

value of the remedies used for preventing the disease, and to this may be added weather conditions which were most favorable to the development of rot, for during June—the most critical period—there were daily showers, preceded by a very hot sun and followed by cool nights with heavy dews. It was a season when fungi of all kinds flourished, and grapes throughout this section were severely attacked by black-rot. The variety treated was the Concord, which is here of all others the one most subject to the disease.

PREPARATIONS USED.

1. Simple solution of sulphate of iron (copperas) :—fifty pounds of the sulphate to twenty-five gallons of water.

2. Bordeaux mixture :—eight pounds of pure sulphate of copper (blue stone) and ten pounds of unslaked lime in twenty-five gallons of water. The sulphate of copper was dissolved in two gallons of hot water and then poured into a cask containing eighteen gallons of water; the lime was slaked with five gallons of water which was then poured slowly into the same cask, through a common flour sieve. The fluid in the cask was well stirred while the lime mixture was being added.

3. Ammoniacal solution of carbonate of copper :—five ounces of the copper carbonate dissolved in one quart of strong ammonia water (*aqua fortis*) to twenty-two gallons of water. The dissolved carbonate of copper and ammonia were kept in a glass-stoppered bottle until required for use, when the solution was poured into enough water to make up twenty-two gallons.

TIME OF MAKING THE APPLICATIONS.

On March 12, before the buds had commenced to start, the vines experimented on were washed thoroughly with sulphate of iron solution (No. 1). This was accomplished by using the spraying-pump, the stocks being thoroughly drenched by the spray. The object of this washing was to disinfect the vines, freeing them as far as possible from the spores of the fungus likely to be resting upon them. A liberal application of the same material was made to the soil about the vines, where there was much infectious material in the shape of fallen leaves and rotted berries of the previous year.

During the growing season the Bordeaux mixture and the ammoniacal solution of carbonate of copper were used, each being applied with the spraying-pump five times to separate rows; first, on April 3, when the young shoots were from four to twelve inches long, and the other applications at nearly regular intervals until June 22. The same vines were treated each time with the same preparation. On August 9, there was an abundance of both preparations still adhering to the foliage in spite of the frequent and heavy rains during the three weeks preceding that date. In fact there was so much of the Bordeaux mixture on the clusters of ripening fruit that, as this was designed for the table and not for wine-making, it was feared its market value would be affected. In view of the possibility of this result a sixth application of the remedies, originally planned, was not made.

GENERAL OBSERVATIONS.

The leaf-spot disease or black-rot on the foliage, began to appear May 9, and very soon it became quite general throughout the vineyard, although there was decidedly less of it on the vines treated with the Bordeaux mixture than on those treated with the carbonate of copper

or on those untreated; between these last I could detect no appreciable difference, and early in the season I was led to doubt the efficacy of the ammoniacal solution of sulphate of copper. Later developments, however, made it evident that this preparation was scarcely, if at all, inferior as a preventive of rot to the Bordeaux mixture.

On June 8 a single berry affected with black-rot was found in our experimental plot. Between this date and June 22, was a period of showery and damp weather, like that above described, and there was a general and severe attack of the rot. The berries on the treated vines were much less affected than those on the untreated. From ten vines of the former, I picked, June 22, four quarts of specked and more or less decayed berries, while the same amount much more shriveled and badly diseased were gathered from three untreated vines. This was a fair comparative showing of the effects of the treatment at that time.

During July, a second attack occurred which somewhat affected the treated grapes, but by no means to the same extent that it did those which had received no application; the latter were nearly all destroyed.

RESULTS OBTAINED.

The results of the experiments were decidedly in favor of the treatments. The value of the Bordeaux mixture in treating black-rot, affirmed by me in 1888, was again demonstrated, and the indications were that the ammoniacal solution of carbonate of copper is equally efficacious. I certainly could see no difference in the effects of these two compounds as used in the experiments. The treated vines lost about a third of what might be estimated as a full crop, or of what would have matured had it not been for the rot, while the loss on the untreated vines was practically complete, there being hardly more than four to five per cent. of the berries unaffected. On June 9, the crop throughout the vineyard promised to be one of unusual abundance.

Considering the very unfavorable character of the weather, the thorough infection of the vineyard from the disease of the previous year, and especially the great susceptibility to rot of the variety under treatment, the measure of success attained was highly gratifying. We cannot hope to free a vineyard from disease in one season, nor yet in two; but we may hope, and confidently, that with each succeeding season of carefully conducted treatments, success will be more and more complete.

In seasons of great humidity the rot will doubtless occasion some loss, however diligently we may strive to check it, and the possessors of small vineyards, (of an acre or less) who raise only table grapes, are recommended to use paper bags. These put on in good season are a certain protection against the rot, and at the same time will prevent the depredations of insects and birds. The proprietor of the vineyard where our experiments were conducted put on many bags when the

vines were in full bloom; in these the grapes matured perfectly and were finely colored.

Those who, here in the East, raise grapes for wine, can and ought to select for culture well known resistant varieties like the Norton and Ives, or those originating from such species as Vitis rupestris, V. Berlandieri, etc. The influence, if we may use the expression, of black-rot over these sorts is comparatively slight, and they will consequently respond more readily to the treatments.

The winter treatments with the sulphate of iron, I regard as highly important. Instead of sulphate of iron solution, I would recommend the use of sulphate of copper, one pound of the sulphate to about five gallons of water. The application of this to the pruned vines will be very certain to destroy all the germs of disease which may be resting upon them.

Unless the grapes are grown for wine, I would discontinue the use of the Bordeaux mixture after the second application, as its presence on the clusters is likely to depreciate the market value of the fruit, and in the succeeding treatments I would use only the ammoniacal solution of carbonate of copper. Should this latter compound prove to be entirely as efficient as the Bordeaux mixture, it will be generally adopted for all the treatments, as it is less expensive, and being a clear liquid is sprayed with less difficulty.

LATER EXPERIMENTS.

The work in treating vines for the prevention of black-rot was continued in Mr. Allen's vineyard during 1890 and 1891. The same apparatus for applying the preparation, namely, the Eureka Sprayer, was used; the preparations being the Bordeaux mixture and the ammoniacal solution of carbonate of copper. The work and the results obtained in 1891, are presented in the following communication kindly furnished me by the proprietor of the vineyard:

KNOXVILLE, TENN., November 6, 1891.

Prof. F. LAMSON-SCRIBNER,

Director of Agricultural Experiment Station.

Dear Sir:—Your request for statement of my experience with black-rot and mildew for the past season reached me in due time. In reply I will give you dates from memory only, as my memoranda are out at the vineyard.

On the 14th of March I drenched the vines of the whole vineyard with a nearly fifty per cent. solution of copperas, applying it to both sides of the rows, driving it thoroughly into every crevice on both vine and trellis. About April 12th I treated them with the Bordeaux mixture, usual formula. The buds were beginning to swell and the first treatment had a tendency to check their growth somewhat. I continued the applications about every two weeks, until the first of June,

when I began applying the carbonate of copper solution :—3 oz. copper carbonate, 1 qt. liquid ammonia, 22 gallons of water,—and continued this treatment every two weeks until the fruit began to color, July 12th. Black-rot first made its appearance on the leaves May 4th, and from this date it was quite thickly scattered throughout the vineyard, except on the Delaware. The first attack on the berries occurred June 3rd; from that date until June 15th they rotted badly. Weather hot, with showers night and day at frequent intervals, which prevented the applications being made. Weather then changed to hot and dry, and the rot gradually ceased. No second attack made its appearance. I will give the varieties treated in the order in which they ripened :

Wyoming Red	June 28.
Delaware	August 3.
Concord	August 13.
Catawba	August 20.

There were no vines left untreated. Now as to results :

Wyoming Red	10 per cent. loss.
Delaware	Splendid crop, lost none.
Concord	25 per cent. loss.
Catawba	25 per cent. loss.

Mildew did not appear until long after the crop was gathered, and then on those leaves that had grown since the treatments were discontinued, the applications being still visible on some few leaves which had escaped the frost on November 1st. The powder left by you I applied as directed, when the dew was on, watched it closely, but could see no particular benefit derived from its use. It burnt the foliage some where applied too thick. I think the treatments for black-rot are effectual for mildew.

As to the profits of treatment : I believe that without treatments we would hardly realize more than ten per cent. of one whole crop, take one year with another, in this climate. I have nearly five acres of vineyard. I sold to one firm in Knoxville eight thousand pounds of fine fruit. A great many were sold and used at the vineyard, besides what went into jellies and wine, of which no account was made.

I herein also give you my experience with two apple trees, three pear trees and one peach tree. I applied the Bordeaux mixture to them at the same time and in the same quantity. One apple tree bore a splendid crop of fine smooth apples, the other about one-half crop. The pear trees were well loaded and of good quality, free from defects, as also the peach, while the fruit on other untreated peach trees adjoining nearly all rotted just at the time of ripening. I applied the carbonate of copper solution to potato vines which were being destroyed by the potato bug. The bugs left on the first application and troubled me no more.

I have as much faith in the carbonate of copper solution as I have

in the Bordeaux mixture. Which is the most effectual in its work is difficult for me to decide, but I would not on any account use the Bordeaux mixture after the first of June on grape-vines on account of the lime adhering to the clusters.

Hoping this statement may be of use to you, I remain,

Respectfully yours,

J. T. Allen.

II. BROWN ROT. (*Peronospora viticola.*)

Brown-rot of grapes is caused by a fungus very different from that which causes black-rot, but it resembles the latter in its habit of attacking all the green parts of the vine—young shoots, leaves and berries. In fact, it is best known through its action on the foliage, few suspecting that the *downy mildew*, so often seen on the under side of grape leaves, is the same fungus which destroys the berries by *brown-rot*. By repeated attacks on the foliage this fungus really does more serious injury to the vine than the parasite of black-rot, for it causes the leaves to turn brown and fall prematurely, thus preventing the proper ripening of both the fruit and new wood; it may ultimately cause the death of the vine.

Peronospora viticola, the fungus under consideration, is a plant with clearly marked characters, as readily defined as those of the vine upon which it feeds. Every one knows that the leaves and other parts of the vine are made up of tissues composed of cells of various shapes, and it is between these cells that the vegetative part—the mycelium—of the fungus grows. At *a*, in Fig. 22, is shown, very highly magnified, a couple of cells from a grape berry, around which the mycelium of the fungus (the shaded portion) has grown. Although this mycelium does not enter the cells through the walls, it pushes into them short, rounded branches, called haustoria or suckers, by means of which the fungus draws from the host the food necessary for its own support. These suckers are usually quite abundant, and their appearance, under the microscope, is well illustrated in the above figure. After the fungus has grown for a time within the tissues of a leaf, the mycelium throws out branches through the breathing pores, which are chiefly confined to the under side of the leaves, and it is upon these branches that the

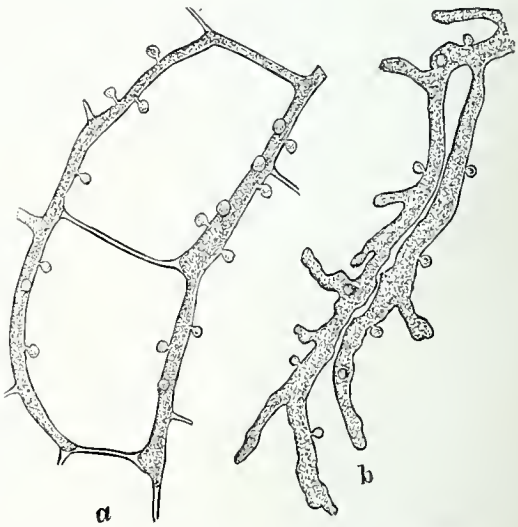


Fig. 22. Mycelium of the brown-rot fungus.

fungus bears its fruit—the spores. Three of these branches, thickly covered with spores, are illustrated in Fig. 23, very much magnified. By their great numbers these fruiting outgrowths of the parasite form the more or less extended frost-like or downy patches observed on the under side of the leaves, and called "mildew." This stage of the fungus is familiar to every grape-grower. It should not be forgotten, however, that the fungus must have been vegetating for some time within the tissues of the affected parts before this outside development takes place; it is also a fact that the parasite may grow most vigorously within the tissues and do most serious harm, without ever appearing upon the surface at all. It seems to be impossible for the fungus to force an exit through the outer tissues of some of the organs which it may infest. This is the case with the berries after they have reached a certain stage of growth. Attacked when quite small, the berries will often show upon their surfaces the fruiting branches of the parasite and appear "mildewed," but later, when the attack results in brown-rot, the fungus rarely appears upon the outside.

Fig. 23.

Brown-rot progresses rather more slowly than black-rot, but the presence of the disease is soon detected. The affected berries assume a grayish tint or have a color less clear and vivid than those which are healthy; marked discolorations appear here and there over the surface, particularly near the stem end, and at these points the skin becomes more or less depressed by the shrinking of the underlying tissues. As the disease progresses, the berries become more and more withered and lifeless in appearance, finally becoming uniformly brown, (see Plate VI., Fig. 2). They do not dry up and present the hard and prominent wrinkles of berries destroyed by black-rot, nor are their surfaces covered by the small black pimples which are characteristic of that disease. It not unfrequently happens that the berries are attacked by both the parasites above named at the same time, and then it is difficult to detect the peronospora except by a microscopic examination of the mycelium.

Aside from the spores borne on the out-growing branches of the mycelium, the peronospora produces another kind on the mycelium within the tissue of the host-plant. While the former are generally short-lived and soon lose their vitality upon drying, the latter live through the winter season and serve to propagate the fungus the ensuing spring. The first are called the "summer spores," the second the "winter spores." Both are shown in Fig. 24, drawn to the same scale, *b* representing the thick-walled "winter spores."

Fig. 24. Spores.

TREATMENT OF MILDEW AND BROWN-ROT.

It has been fully demonstrated that spraying the vines with the preparations containing sulphate of copper, such as the Bordeaux mixture or *eau celeste*,* are, when properly applied, thoroughly efficient remedies for mildew and brown-rot. The latter preparation (*eau celeste*) has been repeatedly employed in the vineyards of Northern Ohio and Western New York, where brown-rot most prevails, and has almost without exception given excellent results. In ordinary seasons three applications of these remedies should be made at intervals of from three weeks to a month, beginning about the time the vines are in bloom, or better, perhaps, as soon as the first leaves are fully formed. These applications ought always to be made whether there is any appearance of the disease or not. We must keep in mind the fact that to avoid the ravages of these fungus parasites, they must be treated *preventively*. We must *prevent* their entering the tissues of the host plant—the vine—by applying to the latter, in advance, some substance which will destroy or prevent the germination of the spores which may fall upon it. It is therefore important to begin the applications early in the season. The amount of the solution used per one thousand vines will depend upon the style of pruning, age of the vines and kind of sprayer used. We roughly estimate that for the first application twenty gallons should be used, for the second, thirty, and thirty-five or forty for the third. In very wet seasons the number of the applications ought to be increased to five or six, by reducing the intervals of time between them. In order to avoid the later attacks of downy mildew on the foliage the vines ought to be sprayed immediately after the vintage.

It is absolutely essential to success that the preparations be properly applied, and this cannot be done unless a good spraying apparatus be used. The most approved style of pump and sprayer for vineyard use is illustrated, in operation, in Fig. 21. The tank, which holds four to six gallons of the fluid, is carried upon the back of the operator, knapsack-fashion, and to this tank is attached the force pump, which is worked by a lever that passes forward to the right hand. A piece of rubber hose leading from the pump and terminating in a suitable nozzle for giving a good spray, is held and its point directed by the left hand. With such an apparatus one man can spray four to six acres of vines per day. As now made, these spraying-pumps are not only serviceable in the vineyard, but they are also generally useful for spraying all kinds of plants except large trees.

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* Dissolve one pound of sulphate of copper in two gallons of hot water; when dissolved, and the water has cooled to the ordinary temperature of the air, add one and one-half pints of liquid ammonia (strength 22 degrees Beaume); keep this solution in a tightly closed vessel. When ready to use, dilute by adding twenty-five gallons of water. This preparation is liable to burn young and tender foliage, particularly of the Æstivalis class.

III. ANTHRACNOSE OF THE VINE AND BIRD'S-EYE-ROT.

Another fungus parasite of the vine produces upon the leaves, (Plate VI. Fig. 4,) but more especially upon the canes, an affection which the French have named anthracnose. The same parasite also attacks the berries, causing a form of rot which is known in some localities as bird's-eye-rot. In some regions, particularly where the air is moist and the soil poorly drained, this disease often occasions serious injury to the young canes (see Fig. 25). It is scarcely less common on the berries, although by no means so destructive to the fruit as either black- or brown-rot. We have known of instances, however, of its taking every berry on well-fruited vines of Elvira, but such cases are rare.

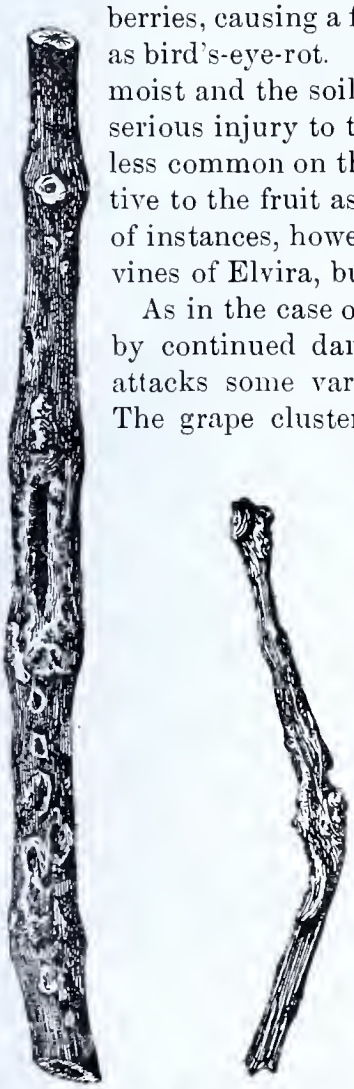

Fig. 25. Illustrates the appearance of grape shoots attacked by anthracnose.

As in the case of mildew and black-rot, the fungus is favored by continued damp weather or an excess of moisture, and attacks some varieties of grapes more severely than others. The grape clusters are sometimes attacked while they are yet in the bud, and from the opening of the season until its close the attacks may be continued. There is probably no vineyard in the country, this side of the Rocky Mountains, entirely free from this pest. The Jacquez is a variety especially subject to it, but we have seen it on many other sorts, particularly the Elvira and Catawba.

On the berries the presence of this fungus is indicated by the appearance upon any part of the surface of reddish brown or nearly black specks. These gradually increase in size to one-eighth or one-fourth of an inch in diameter, retaining a circular outline (see Plate VI. Fig. 3). The now quite large spots usually become gray in the center, and between this and the dark bordering line there sometimes appears a well-defined ring of bright red or vermilion, when the spots suggest the colorings of a bird's eye, whence the name applied to this form of rot.

During the progress of the disease there is no general withering or softening or browning of the berries, and the parts not actually covered by the spots remain green for a long time; beneath the spots the tissues gradually lose their turgescence, the cells

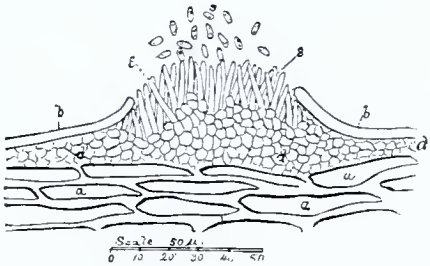

Fig. 26. The fungus of anthracnose in fruit.

collapse and the cell-walls become dry and hard. In advanced stages of the disease the berries, reduced to one-fourth their original size, still exhibit the outlines of the original spots. When only slightly attacked, the berries often become irregular in shape, the part unaffected continuing its developement, while the portion underlying the spots is checked in its growth. When the grapes are attacked while quite small, and not too severely affected, they may outgrow the disease, the only trace of it left being a gray or brown scurf here and there on the surface. Sometimes when attacked on one side only, the further growth of the healthy side will cause the side diseased to crack open, exposing the seeds. The latter are sometimes pushed completely out by the unequal growth of the parts.

Unlike the fungi of brown- and black-rots, that of bird's-eye-rot does not penetrate deeply into the tissues of the host-plant. The germinating spores penetrate the cuticle and epidermis, and its further growth takes place just beneath the latter. This growth distends and uplifts the epidermis, finally rupturing it when nearly the entire plant-body of the fungus becomes exposed. From this exposed part of the fungus spring numerous short branches, upon which the spores are borne. This stage of the fungus is illustrated in Fig. 26; *a*, *a*, are the dried and much flattened cells of the tissue of the berry; *b*, *b*, is the cuticle of the berry, and *d*, *d*, represents the plant body of the fungus. At *e*, *e*, are the upright branches which bear the spores seen detached above. A comparison of this figure with those preceding will show how diverse in their habits of growth are the fungi which cause the best known forms of grape-rot.

TREATMENT OF ANTHRACNOSE.

The treatment for anthracnose is to wash the vines after pruning and before the buds begin to swell in the spring, with a strong solution (forty to fifty per cent.) of sulphate of iron, or a strong simple solution of sulphate of copper (using two pounds to ten gallons of water.) The solution may be applied with a common mop or by the spraying-pump. This treatment repeated for several successive seasons will usually free the vineyard of the disease. If the malady appears during the growing season it may be checked by applications of sulphur, or sulphur and lime mixed in equal parts, or by using one of the powders referred to below. Anthracnose is not likely to do much damage in vineyards that are well treated for mildew or black-rot.

IV. GRAPE-LEAF BLIGHT.

Grape-leaf blight is very prevalent here, usually appearing after the vintage, and as its effects may be mistaken for mildew, its special characters should be noted. This disease is described and the fungus which causes it figured in the writer's work on the "Fungous Diseases

of the Grape and Other Plants,"* and from this we quote the following:

In a vineyard of Concords, Delawares, Catawbas and Wyoming Red, which we have had under inspection, the leaf-blight has appeared on all the varieties, but most abundantly on the Catawba and least on the Delaware. Early in June in 1889, it had spread over some of the Catawba vines, even to the highest and most exposed leaves, the blight spots being numerous and unusually large. A small vineyard of Concords in this vicinity (Knoxville), which we visited about September 10, 1889, presented a remarkable instance of the severity of this disease. From our first glance at the vineyard we thought that the foliage had been injured or rather destroyed—for practically it was destroyed—by the downy mildew, and we were much surprised when, upon closer inspection, even after careful search, we found no trace of the mildew in it; but the blight fungus was everywhere, much of the foliage had already fallen through the action of the parasite, and there was not a leaf remaining on the vines that did not show the marks of the disease. These were spotted and blotched in all degrees, some but slightly, others covered with numerous and rather small spots, while others still, and these were in the large majority, presented a blotched and blackened appearance, as if burned with a hot iron. Such was the condition of the foliage that the possibility of the blight becoming, under some circumstances, a serious pest, at least in this latitude, could not be questioned. The fruit in the vineyard had been harvested at the time of our visit, so it is very likely that the crop was little if at all affected by the blight. The vines, however, could not pass uninjured this early destruction of the foliage, a fact which doubtless will be made evident next year by an enfeebled growth and diminished crop.

The spots of the leaf-blight (see Fig. 5 on Plate VI.) are readily distinguished from those caused by black-rot by their more irregular outline, much darker color, and absence of the numerous, usually concentrically arranged, black points or pustules which characterize the latter. In the violent form in which the disease occurs here, the spots are much larger than shown in the figure, still more irregular in outline and very dark brown in color, often appearing almost black. The leaf tissue within the spots is killed and becomes dry and brittle. Such large and irregular spots may be mistaken for the effects of mildew, but the entire absence of the white, frosty or downy external growth of this parasite serves to distinguish it. Besides, we can usually detect the blight fungus with the naked eye by folding a diseased leaf over the finger and looking across one of the spots against the light or a white surface. In this way we see the dark spore-bearing filaments, or rather bundles of filaments, standing upright, as fine, hair-like projections, scattered more or less thickly over the surface.

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*"The Fungous Diseases of the Grape and Other Plants and their Treatment," by F. Lamson-Scribner, published by the J. T. Lovett Co., Little Silver, New Jersey.

No attention has been paid to the treatment of this disease, for it attacks only the foliage, and has generally been regarded with indifference. We have seen, however, that in exceptional cases at least it may do serious injury to the vines, and a knowledge of its appearance and habits becomes important. Certainly all the fallen leaves harboring the fungus ought to be destroyed, as one means of mitigating the ravages of this parasite, for the mycelium of the fungus lives through the winter in these fallen leaves, and stands ready to produce a new crop of spores upon the first warm days of spring. What effect the cupric solutions, employed in treating mildew and rot, may have upon it, is yet to be determined. Our own observations in this direction are rather limited, but lead us to infer that they will be of no avail. We have seen the fungus in full development, and well fruited on leaves thoroughly coated with the Bordeaux mixture.

TREATMENT OF FUNGOUS DISEASES OF PLANTS.*

When a fruit-grower discovers that a fungus is destroying or damaging his plants or crops, the first question he asks is, How can I prevent it?

Very rapid progress has been made, within the last few years, in discovering means and methods for destroying these fungi or preventing their attacks. In the spring of 1886 I prepared a little circular, which was distributed from the United States Department of Agriculture, urging the trial in this country of several preparations having sulphate of copper for a base, among others the Bordeaux mixture; recommending these, I say, and urging their trial for preventing mildew and black-rot of the grape. This was the first official document of the kind published in this country, and to look over the ground now and note what has come from it, the result seems really marvelous. Bordeaux mixture has become almost a household word in the homes of the horticulturists throughout the length and breadth of the land. The preparations having a copper salt for a base are in the hands of every enterprising horticulturist, and he is learning how to use them to his advantage, protecting his crops, as they certainly do, from many of his worst fungus foes. As one result of the multiplied use of these compounds in treating fungus diseases, our manufacturing chemists now keep them in stock, and the amount of sales for the purposes here mentioned amount, probably, to hundreds of tons annually. They are used for combating grape-mildew, grape-rot, potato-blight and rot, pear-leaf-blight, apple-scab, brown-rot of the peach, and a host of other plant diseases, and in every case where they have been used intelligently, they have almost invariably yielded good results.

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* Extract from an address delivered at the first annual meeting of the East Tennessee Horticultural Society, at Harriman, Nov. 11, 1891.

There was little done in 1886 in treating rot and mildew, chiefly for the reason that no one believed we could prevent grape-rot, but more especially because we lacked the suitable apparatus for applying the remedies recommended. Early in 1887 several styles of the spraying-pumps used in France were introduced by me, under the authority of the U. S. Commissioner of Agriculture, and by the direction of the Commissioner, I started out with the determination of making experiments myself in combating the diseases of the vine with the copper compounds which we had recommended the year before. In the middle of May, 1887, I made the first spraying in the vineyard of Col. Wharton J. Green, at Fayetteville, N. C.; and immediately following began operations in the vineyard of Mr. H. L. Lyman, at Charlottesville, Va., and then in that of Col. A. W. Pearson, at Vineland, N. J. Pumps and material were at the same time furnished to Mr. Hermann Jaeger, of Neosho, Mo., and Mr. T. V. Munson, of Denison, Texas, and they were directed to make similar experiments in their respective localities. We thus had five stations at widely distant points, and the results of our work were published by the Department (*Bull. 5, Sect. Veg. Pathology*).

These results, while not so marked as had been hoped, were sufficiently encouraging to lead us to continue the recommendations of the copper compounds and to renew our experiments in 1888. We had learned much by our experiments in 1887. We were beginners then and had considerable to learn. The experience gained that year enabled us to do more effective work the year following. One of the chief points learned was that we must begin the battle very early in the season, if we would secure the victory. The fungus of black-rot remains alive through the winter in the fallen, withered berries, which it destroyed during the summer, and stands ready to renew activity in the first warm days of spring. It then produces a crop of spores, which are discharged with some force from the berries and scattered about to fall upon the vine or its parts and work anew its ravages. So we must begin in season and fight this pest so vigorously that it is left no opportunity to do us harm. To accomplish this we must spray the vines or wash them before the buds begin to swell in the spring, with a strong, simple solution of sulphate of iron or sulphate of copper. If we use the sulphate of iron, we should dissolve in water as much as it will take up, or in other words have a saturated solution. If we use the sulphate of copper, we may make it of the strength of one pound to five or six gallons of water. This is a pretty strong solution and it may darken the appearance of the young canes somewhat, but it will do no injury if the buds of the vine have not started at all, and the chances are that it will do a world of good by preventing the germination of the spores of the fungus, which are sure to be present in the vineyard, if the disease was there the year before.

The results of our work in 1888 were positive in their character and the treatment of vineyards for black-rot and mildew is no longer a matter of experiment. If good materials are used and properly applied, good results are certain to follow.

POWDERS.

At the same time that we began experimenting in 1887 with liquid preparations for combating fungus diseases, we tried also a number of powders. We had at first the same difficulty with these that we had with the liquids, which was a suitable apparatus for applying them. Nor was this difficulty overcome before success had been secured by the use of liquids. In this success we rather lost sight of the powders, and few experiments have been made with them. If we can devise simple and effective means for applying the powders, and if they are found to be as effective as the liquids, they certainly present several advantages over the latter. The powders can be procured from the manufacturing chemist in quantities, ready for use at any time when it is convenient to use them, and they will keep indefinitely in this condition. They are much more easily transported in the vineyard, or garden or orchard; and when the dew is on the leaves of the plants to be treated, and there is little or no wind, the plants may be more effectually covered by them than is possible with liquids. And further, insecticides in powder may be added to them without much fear of undesirable chemical reactions taking place.

Every one is familiar with the use of the flowers of sulphur as a destroyer of certain kinds of fungi. It can always be recommended for the treatment of the powdery mildews. Away back in the early days of this century, the value of sulphur in treating the powdery mildew of the vine was recognized, but it has been difficult for some to learn that the *downy* mildews cannot be treated to any effect by the use of this substance. The powdery mildew, being upon the outside of the vine, can be destroyed by the sulphurous fumes which the flowers of sulphur give off, but the downy mildew, growing in the tissues of its host, cannot be acted upon in the same way. We must prevent this latter fungus from gaining an entrance to the host plant, and this is accomplished by covering the vine with a substance which will destroy the young germinating spores. We know what liquids should be used for this purpose, but we must experiment a little further to determine what powders we ought to use. We have published in bulletins or circulars issued by the U. S. Department of Agriculture in 1887 and 1888, formulas for several powers, which for various reasons seem to recommend themselves for the purposes in question. Sulphatine was one of these, and may be prepared by mixing two pounds of anhydrous sulphate of copper with twenty pounds of flowers of sulphur and two pounds of air-slaked lime. This is a valuable fungicide, but

care must be used not to apply it too heavily, or it may burn the foliage of the plants treated. There should be blown over the plants a fine cloud of the powder, which upon settling upon the leaves, should be just perceptible.

Another good powder is what is known as sulphosteatite, sometimes called soapstone powder. We have used this powder prepared as follows:

Anhydrous sulphate of copper ..... 5 lbs.
Soapstone powder, or silicate of magnesia, ... 45 lbs.

The powdered soapstone simply serves as a carrying medium or dilutant for the sulphate of copper, and it assists also in making the copper adhere to the foliage. The powder is exceedingly fine and adheres well, and for the downy mildew of the vine our experiments prove it to be most valuable. We tried it this season on our young vineyard, the vines of which were badly attacked by the downy mildew early in September. We made a couple of applications of this powder with the Leggett Paris-green gun. There was no further development of the mildew; by the first of October the treated vines had developed new foliage and they looked green and vigorous, while at that time a number of vines which had been left untreated, were entirely defoliated. As in the case of sulphatine, care must be used in the application of this soapstone powder. It must not be applied too freely, or the foliage of the plants treated might be injured by it.

Here is the formula for another powder which we are confident will be valuable in treating the downy mildew of the vine, mildew of the cherry, apple and plum, blight and mildew of potatoes, etc.:

Carbonate of copper ..... 1 lb.
Flowers of sulphur ..... 4 lbs.
Soapstone powder ..... 45 lbs.

This can be prepared and sold in quantities at a cost of about two cents per pound. A pound of the powder, if we have the proper kind of bellows, will go a long way, at least covering enough plants to make it as cheap, if not cheaper, than the liquid preparations. We would urge you to try one or the other of the above powders the coming season, giving preference to the last, if you have occasion to use anything of the sort in combating fungi.

LIQUIDS.

Among the liquid preparations which have been used, none have been found superior to the Bordeaux mixture, that coming next to it being what is known as the ammoniacal solution of carbonate of copper. Lime and sulphate of copper enter into the composition of the Bordeaux mixture, and various proportions of this substance have been recommended in its preparation. We would recommend the following:

Sulphate of copper	6 lbs.
Unslaked lime	8 lbs.
Water	24 gallons.

(Or one pound of the copper salt to four gallons of water.)

The sulphate of copper is dissolved in two gallons of hot water and then poured into a cask containing, say, fifteen gallons of water; then we slake the lime with four or five gallons of water, and when cooled, we pour this lime through a sieve into the copper solution, pouring slowly and stirring up the mixture as we go. Finally, add enough water to make twenty-four gallons.

The ammoniacal solution may be thus prepared:

Pure carbonate of copper	5 oz.
Strong ammonia water (*aqua fortis*)	1 qt.
Water	25 gallons.

The ammonia is kept in a glass bottle and the carbonate of copper put into it, where it will dissolve. When required for use, this mixture is put into the requisite amount of water. This preparation is clear and deep blue in color, and is as easily sprayed as water, while the Bordeaux mixture, unless the lime is very carefully strained, is apt to give some trouble in spraying, the particles of lime frequently clogging the spraying nozzle. There is an objection to the use of the Bordeaux mixture upon fruiting plants; it is strongly adherent and its presence upon the ripening fruit is pretty certain to attract attention, and may possibly injure the sale of the fruit when it is marketed. So, in the case of vineyard treatment, it will be well to use the ammoniacal solution of carbonate of copper after the earlier treatments made with the Bordeaux mixture. There is no danger of discoloring the fruit by this preparation, and there is no possible danger to health from the use of either of them. It has been calculated that one would have to eat something over a ton of the grapes treated with the Bordeaux mixture, in order to get into the system a sufficient quantity of copper to be at all dangerous.

SPRAYING PUMPS.

I have already referred to the "Eureka Sprayer." It is a good pump and does its work well, but it is expensive, the price being something over twenty dollars. What appears to me to be just as good and strong a pump as the Eureka, is the "Excelsior Knapsack Sprayer," made by Mr. Wm. Stahl, at Quincy, Ill.; this costs fourteen dollars, which brings it within the reach of nearly every one requiring such an apparatus. A useful pump for spraying large vineyards and orchards, made by the Nixon Nozzle and Machine Company, Dayton, Ohio, is figured in our last Bulletin, page 96. Whatever spraying-pump is used, great care should be taken to keep it *clean*. It should be thoroughly rinsed out with clear water just as soon as the day's work is done. It is particularly important to do this after using the Bordeaux mixture.